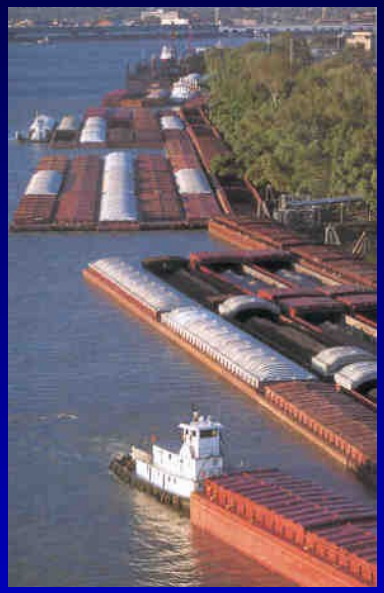
Navigation Systems / Continuing GI R&D Program

Navigation Program Area Review
December 5-6, 2005
Washington, DC



Business Area Leader: Barry Holliday
Program Manager: James Clausner

Navigation Systems
An Integrated Program”

Components

- Navigation Systems (Hydrodynamics, Ice)
  – CHL, CRREL, ITL
- Infrastructure (GSL, ITL, CERL)
- Economics (IWR) and Risk (IWR, CHL, GSL)
- Hydropower (GSL)
- Decision Support (IWR, GSL, CERL, CHL)
- Close Ties to CIRP
- **Industry Input**

Navigation Systems/ Navigation Continuing Program

Presentation Today

- Recent Progress/Completed Efforts
- Describe Research Program
  - Program Structure
  - FY06 Funding Levels
  - Research Needs/Direction
  - Focus Areas and Work Units
  - Tech Transfer –
    - FY06 Workshops
  - ADCP
  - **Receive MSC, HQ Feedback!**

Navigation Systems Only (03-05)

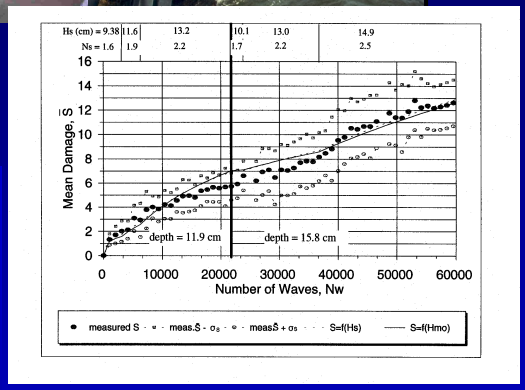
Significant Accomplishments

Structures

Objective: To improve design guidance
lower first costs and minimize O&M

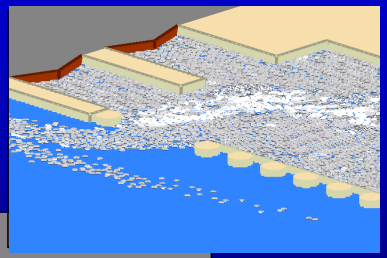
Barge Impact Guidance

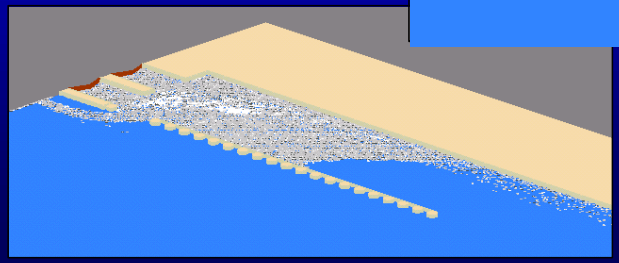
Breakwaters


Hs (cm) = 9.38 11.6 13.2 10.1 13.0 14.9
Ns = 1.6 1.9 2.2 1.7 2.2 2.5
Mean Damage, S
depth = 11.9 cm
depth = 15.8 cm
Number of Waves, Nw
measured S
S=f(Hs)
S=f(Hmo)

ICE PASSAGE THROUGH A GUARDWALL

Simulating ice passage through a gap in a guard wall using calculated water velocities from HYVEL2D



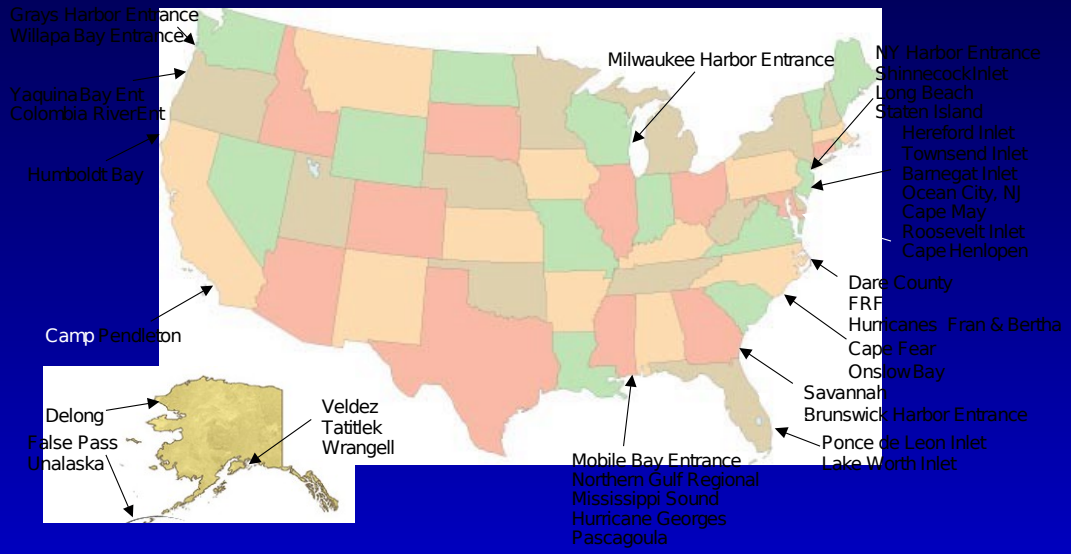


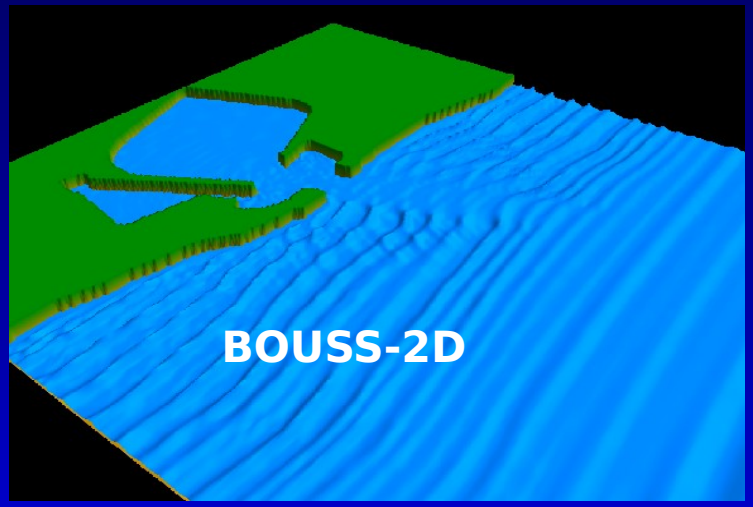
Navigation Systems 05 Significant Accomplishments

Channels and Harbors - Navigability and Vessel Motion

Objective: Develop methods for predicting and assessing vessel motion and provide guidance for safe operations and efficient designs

Recent Corps STWAVE Applications





Navigation Systems Structure

Focus Area	Work Area	Focus Area Manager
Program Management & Tech Infusion		**Jim Clausner**
Deep Draft		**Jeff Melby**
	DD Channels and Harbors	Jane Smith
	DD Structures	Jeff Melby
Inland		**John Hite**
	Inland Hydrodynamics	John Hite
	Inland Structures	Mike Sharp
Hydropower		**Mike Sharp**
Navigation Networks & Asset Management		**Sandra Knight**
	Economic Risk and Reliability	David Moser
	Economic Technologies (NETS)	Keith Hofseth
	Asset Management	Sandra Knight

Overriding Principles

- Link Engineering with Economics
- Include Risk – be aware of Asset Management Decisions
- Develop tools Districts want and will use
- Tie R&D to Performance Measures

Deep Draft Navigation Channels Focus Area

Focus Area Team: Jeff Melby, Jane Smith

- **Continuing beyond 06**
  - Advanced Nearshore Circulation and Sediment Modeling
  - Improved Ship Simulations
  - High Fidelity Vessel Effects, Near-Field Vessel Forces and Mooring
  - Advanced Nearshore Modeling System
  - Risk Analysis of Coastal Structures
  - Improved Condition Indexing for Coastal Structures

Channels and Harbors Work Area

- **Problems**
  - Foreign trade double by 2020, 4,000 + TEU vessels
  - Vessel handling, safety an issue
  - Need to optimize initial channel construction and maintenance costs
- **Products – Improved Channel Design**
  - Predict vessel motions
  - Predict shoaling volumes
- **Benefits**
  - Increased safety
  - Reduced costs
  - Enhanced environmental opportunities, minimize mitigation

Improved Ship Simulations

- **PI: Zeki Demirbilek, Michael Briggs, Tim Shelton**
- **Problem**

  To improve safety, optimize channel design, and include vessel-currents, vessel-vessel, vessel-banks, vessel wakes
- **Products**

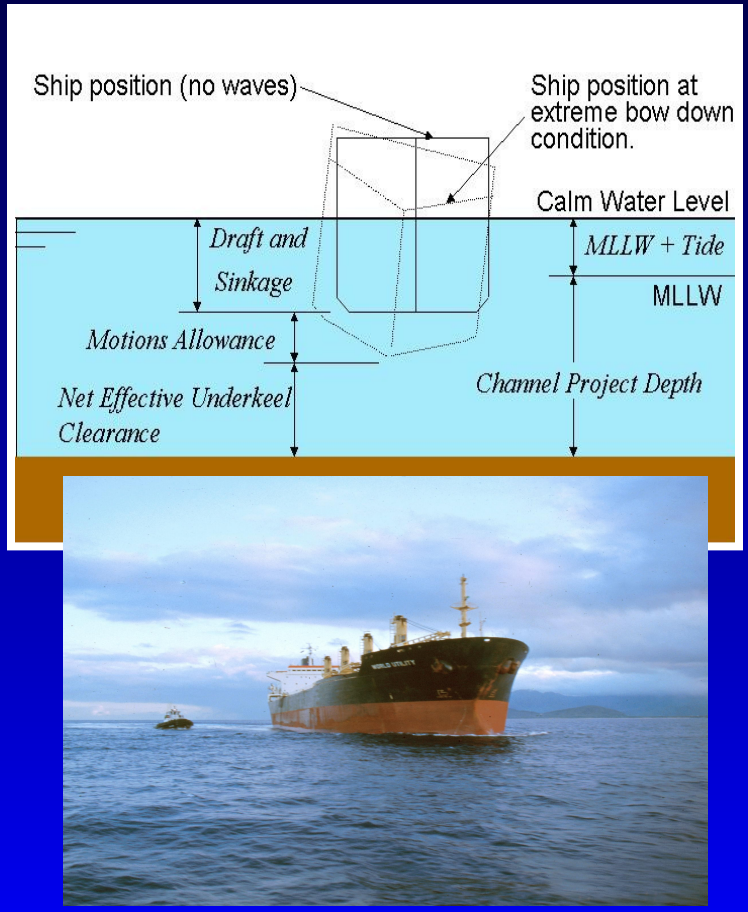
  CHL ship simulator with improved capabilities
- **Benefits**

  Optimized channel dimensions for safe transit

  Reliable vessel simulations

  Reduced over-dredging

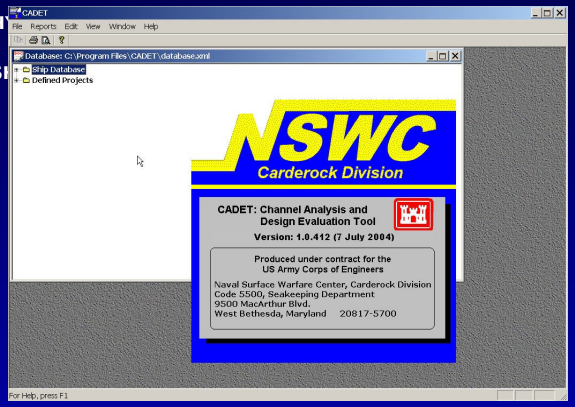
  Training tools



Products

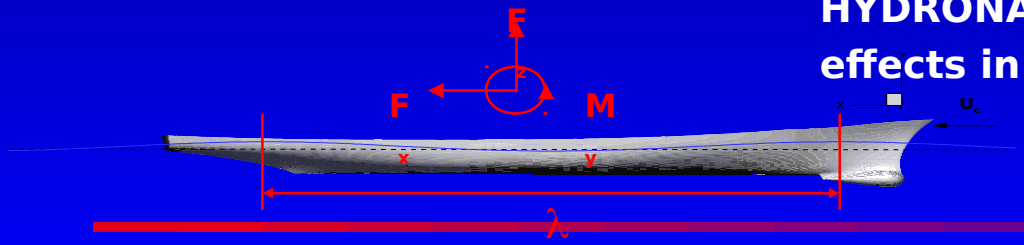
- **CADET**
  - **CADET predicts UKC for design**
  - **Modified from Navy EMOGS**
  - **Commercial vessels**

- **H**
- **SI**


CADET
File Reports Edit View Window Help
Database: C:\Program Files\CADET\database.xml
Ship Database
Defined Projects
NSWC
Carderock Division
CADET: Channel Analysis and Design Evaluation Tool
Version: 1.0.412 (7 July 2004)
Produced under contract for the US Army Corps of Engineers
Naval Surface Warfare Center, Carderock Division
Code 5500, Seakeeping Department
9500 MacArthur Blvd.
West Bethesda, Maryland 20817-5700
For Help, press F1

Approach

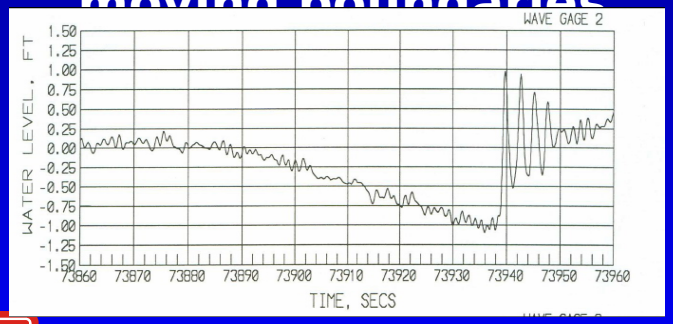
- **Approach Phase I - First 3 years**
  - **Implement existing tools from PIANC and CADET**
  - **CADET: Prediction of ship squat and vertical ship motions in STS**
- **Approach Phase II – Next 3 years**
  - **SHIPM6: Best available 6DOF ship motion package in STS**
  - **HYDRONAV: Vessel blockage effects in STS**



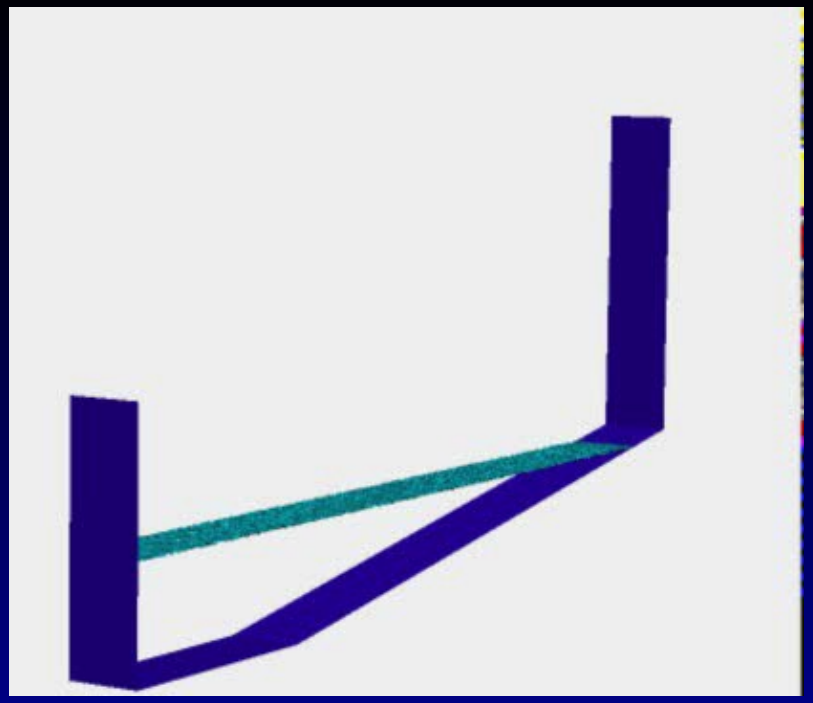
High Fidelity Vessel Effects

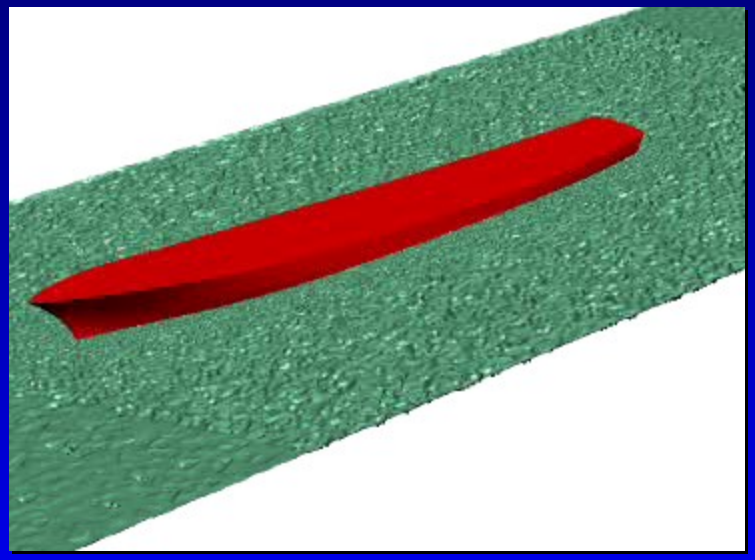
- PI: Charlie Berger
- Problem
  - Difficult to predict vessel waves
  - Complex fluid flow not well predicted by present models
- Final Products
  - 3D Navier-Stokes model with two phase flow and moving boundaries

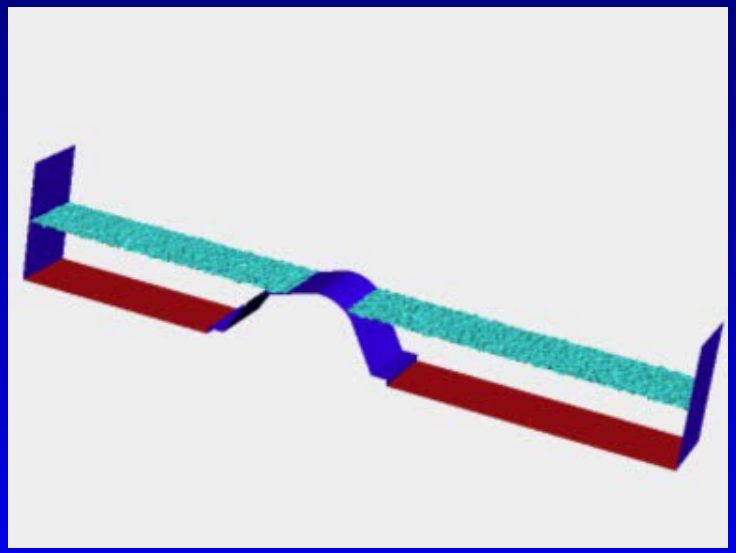
- Benefits: Improved design
  - Vessel wakes
  - Nearshore wave prediction
  - Mooring forces and vessel-to-vessel effects
  - Scour
  - Wave and flow around civil structures (bridges, walls, piles)



Examples of Navier Stokes Applications





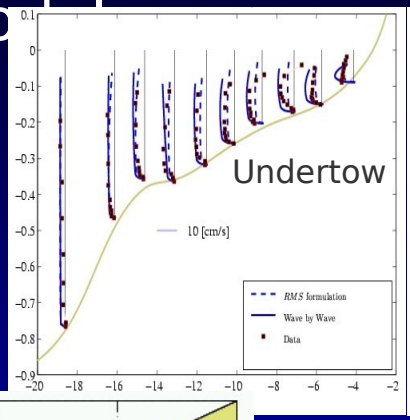


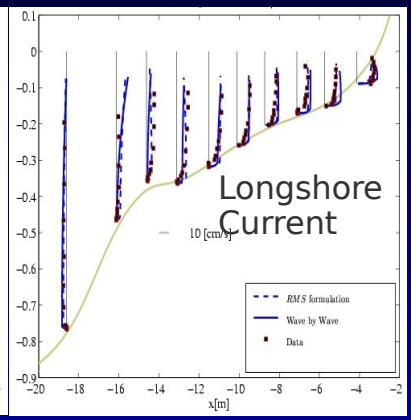
Advanced Nearshore Circulation and Sediment Transport Modeling

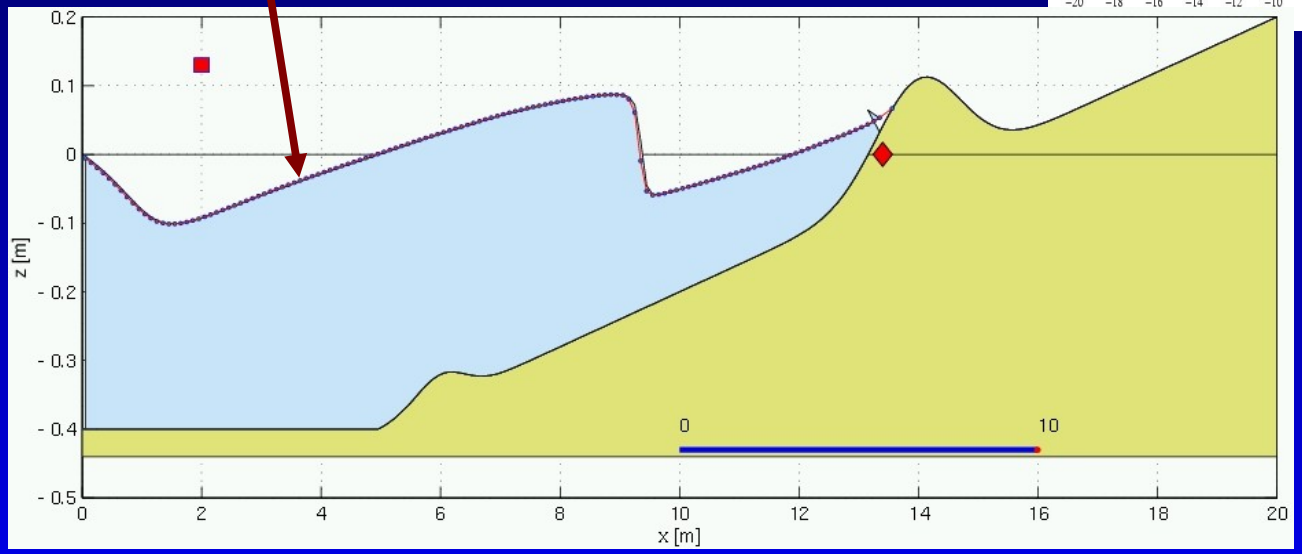
- PI: Brad Johnson, Jane Smith
- Problem
  - Surf zone process difficult to model, 2-3D models required
- Products:
  - Nearshore Circulation Model
    - Waves and winds w/ sediment transport
    - Rip currents, undertow, mass transport
- Benefits: Improved Design
  - Groins
  - Nearshore placement of Dredged material
  - Beach nourishment
  - Dredging volumes

Achievements

- New nearshore hydrodynamic models:
  2-D Model, Q3D Model based on ADH.
  Phase-dependent nearshore mo

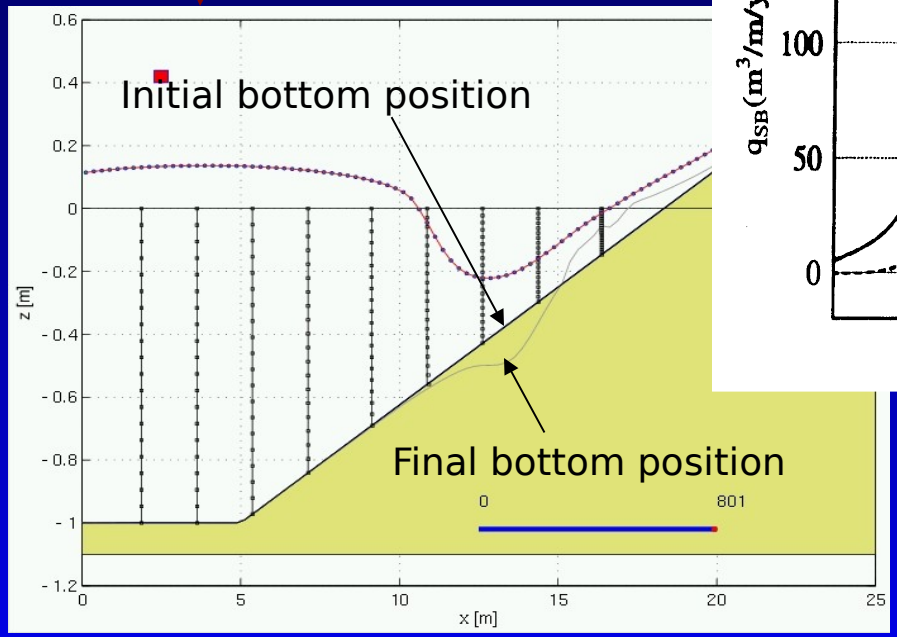


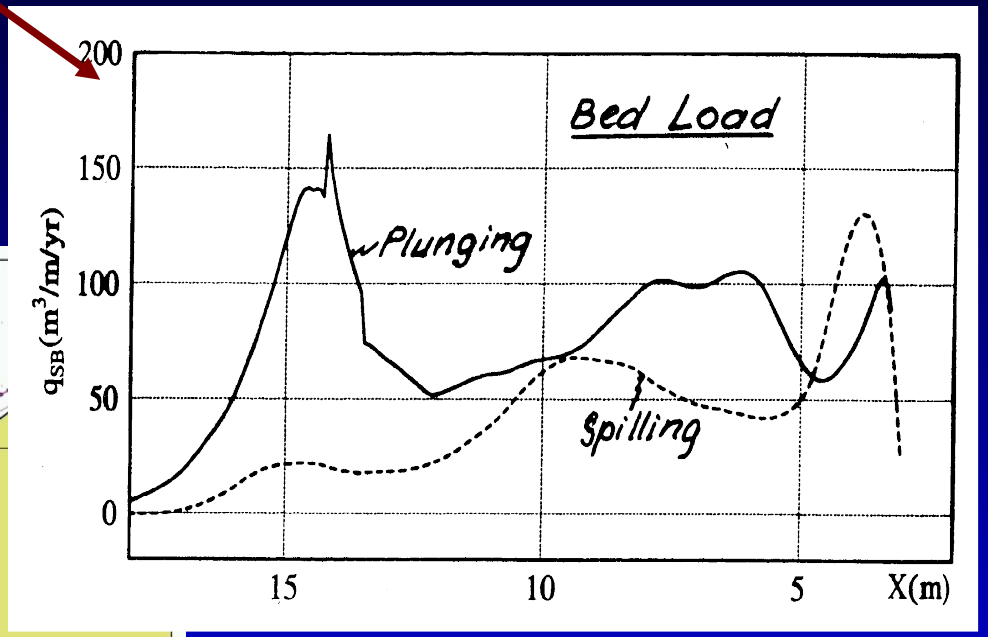




Achievements

- New cross-shore, longshore sediment transport models

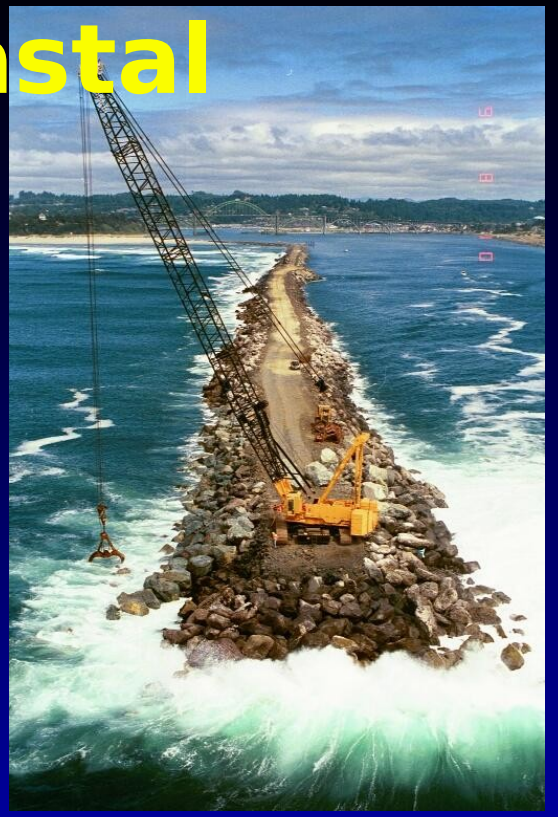




Deep-Draft Navigation Structures Work Area

- **Problems**
  - 140 Deep-draft channel rubble mound structures
  - Degraded structures increase sedimentation and dredging
  - Reduced safety
  - No life-cycle analysis for establishing funding priorities for planning, design, and maintenance
  - Odd assortment of inspection and monitoring strategies
  - No standard asset management
- **Products**
  - Life-cycle damage predictions/linked to state-of-the art economics
  - Take morphology changes into account
  - Expedient design guidance
  - New condition index system
- **Benefits**
  - Improve designs/LCA/reduce costs, dredging, increase safety
  - Better planning and scheduling of repair/rehab
  - Save $, reduce life cycle cost of structure design, construction, repair

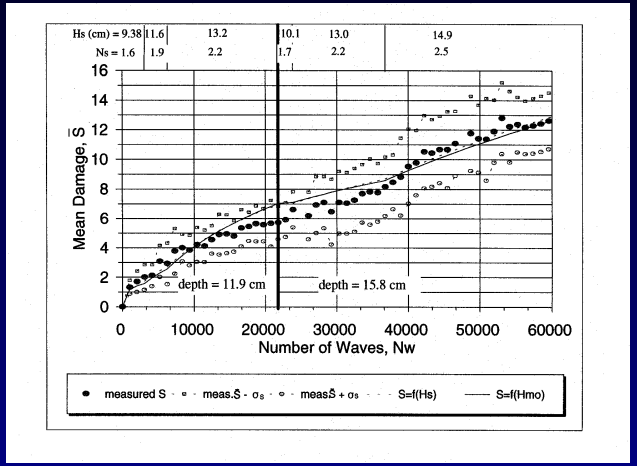
Risk Analysis of Coastal Structures

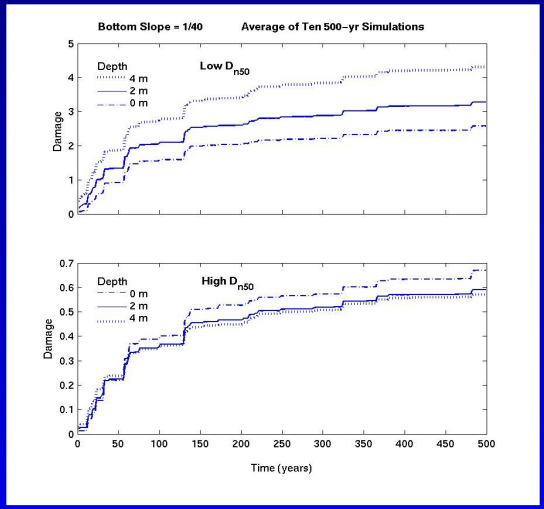


- **PI: Jeff Melby**
- **Team: Steve Hughes, Nobuhisa Kobayashi, Dave Kriebel, IWR**
- **Problem**
  - **No risk analysis tools**
  - **No physics-based design**
- **Products:**
  - **Physics-based design methods**
  - **Reliability methods/partial safety coefficients**
  - **Life Cycle Analysis program for rubble mound structure design**
  - **Web Page for all Corps structures**
- **Benefits:**
  - **Reduced costs for breakwater, jetty design/rehab**
  - **Better planning/scheduling**

Results

- Momentum flux-based **stability equations**
- **Damage equations** for breakwaters, revetments, jetties, berm breakwaters
- **Reliable program** in CEDAS
- **CYCLONE/CSHORE** Monte Carlo life-cycle analysis program
- **ELS** life-cycle analysis and structural optimization system
  - Applied to Chesapeake islands, Neah Bay breakwater, Azores berm breakwater
- **Coastal Structures web page**
- **Coordination** with PIANC WG47, ASCE, Risk EC
- Many journal articles, conference papers, CHETNs



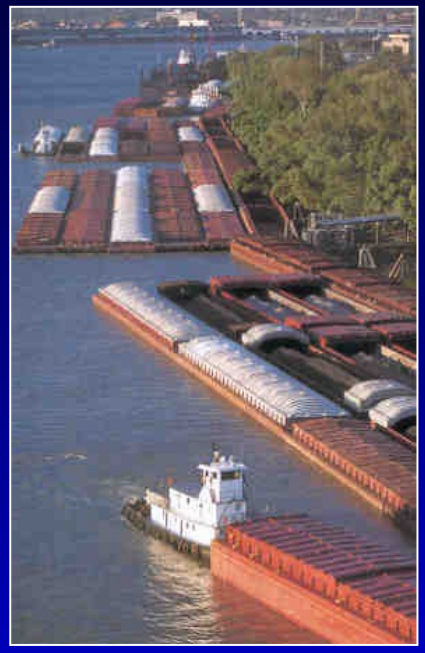


Improved Condition Indexes for Coastal Structures

- PI: Stan Boc
- Problem
  - Inconsistent application of condition indexes
  - Existing condition indexes don't use digital technology
  - No centralized database
- Products
  - Adapt digital technology
  - Create centralized database (GIS based)

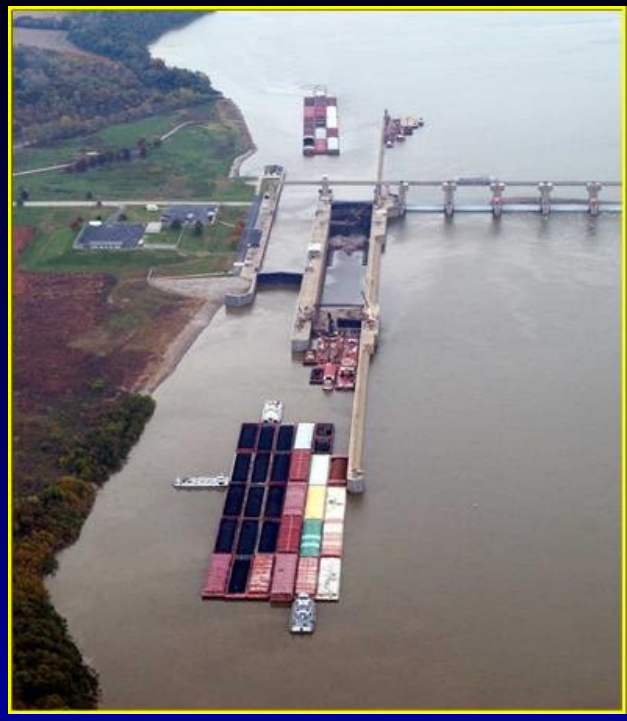
- Benefits
  - Less subjective application of condition indexes
  - Greater ability to compare structures in a region or nationwide, identify trends, collect data for research
  - Improve rehab/repair investment decisions

Inland Navigation Focus Area



Program Manager: James Clausner
Focus Area Team: Mike Sharp, John Hite

Inland Hydrodynamics Work Area



- **Problems**
  - Inland Traffic Increasing/Capacity at limit
  - Increasing capacity w/ safe reliable, envir sustainable channels
  - Improve design tools
  - Vessel impacts, scour, emergency repairs, fish passage, ice/debris, fill empty systems, float in construction
- **Products**
  - Vessel Impact Models
  - Improved/Innovative Lock Entrance Structures
  - Emergency Repair Structures/float in construction
- **Benefits**
  - Reduce Costs, increase safety
  - Reduced environmental impacts
  - Increased reliability, increase capacity

Inland Hydrodynamics Work Area
Work Units

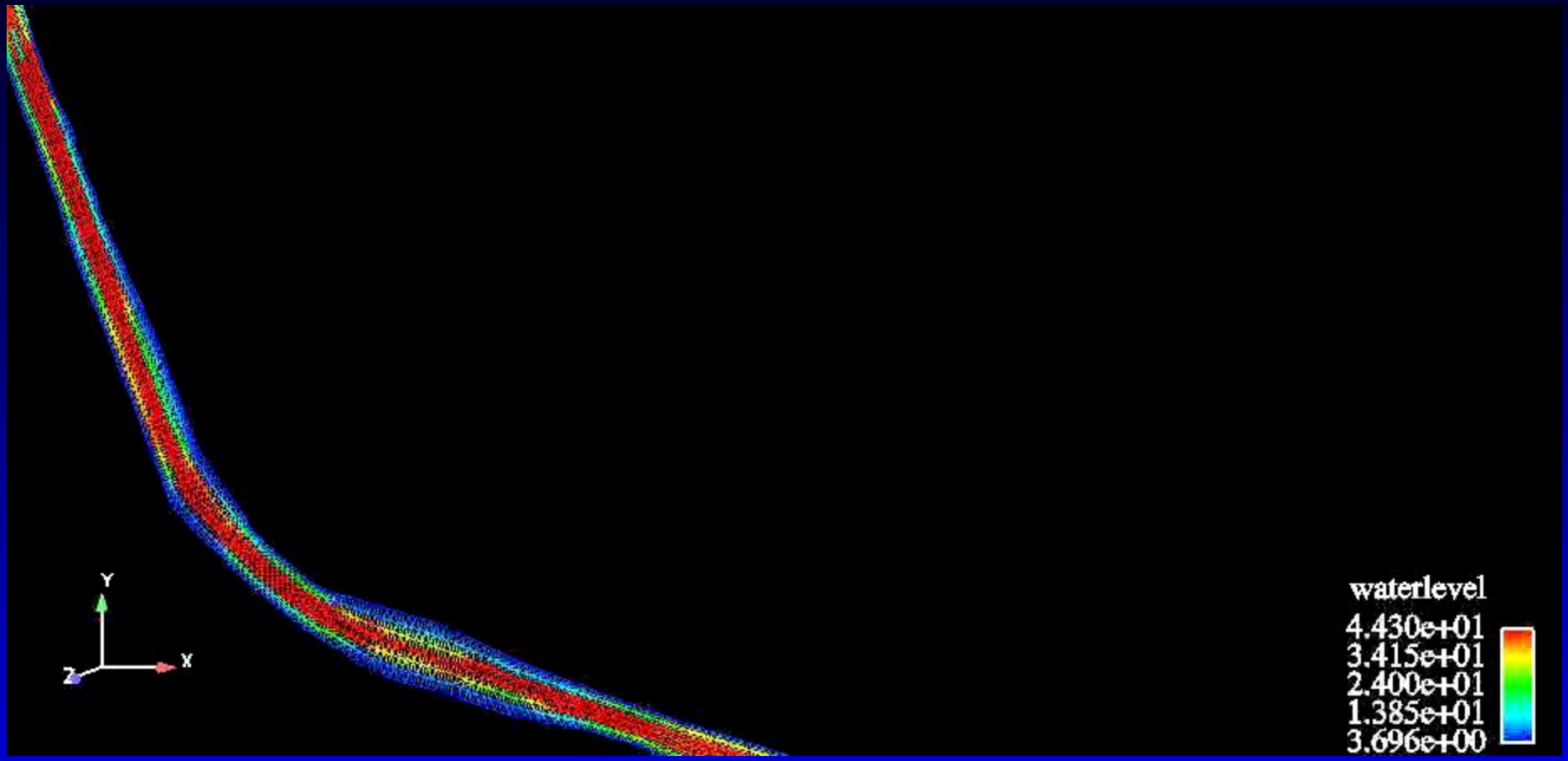
- Existing Work Units
  - Hydrodynamic Design for Inland Structures
    - Environmental Effects
    - Hydraulic Structure Design
    - Hydraulic Structure Performance
  - Barge Impact Load Models and Criteria
  - Scour Protection Assessment

Hydrodynamic Design for Inland Structures: Environmental Effects

- **PI: Berger/Stockstill**
- **Problem:**
  - **Need improved models to assess environmental effects from project operations and vessels**
- **Products:**
  - **CHL CFD model (ADH) modified for vessel effects and sediment transport**

- **Benefits:**
  - **Improved Channel/Structure Design**
  - **Improved environmental quality**
  - **Better knowledge of vessel effects**

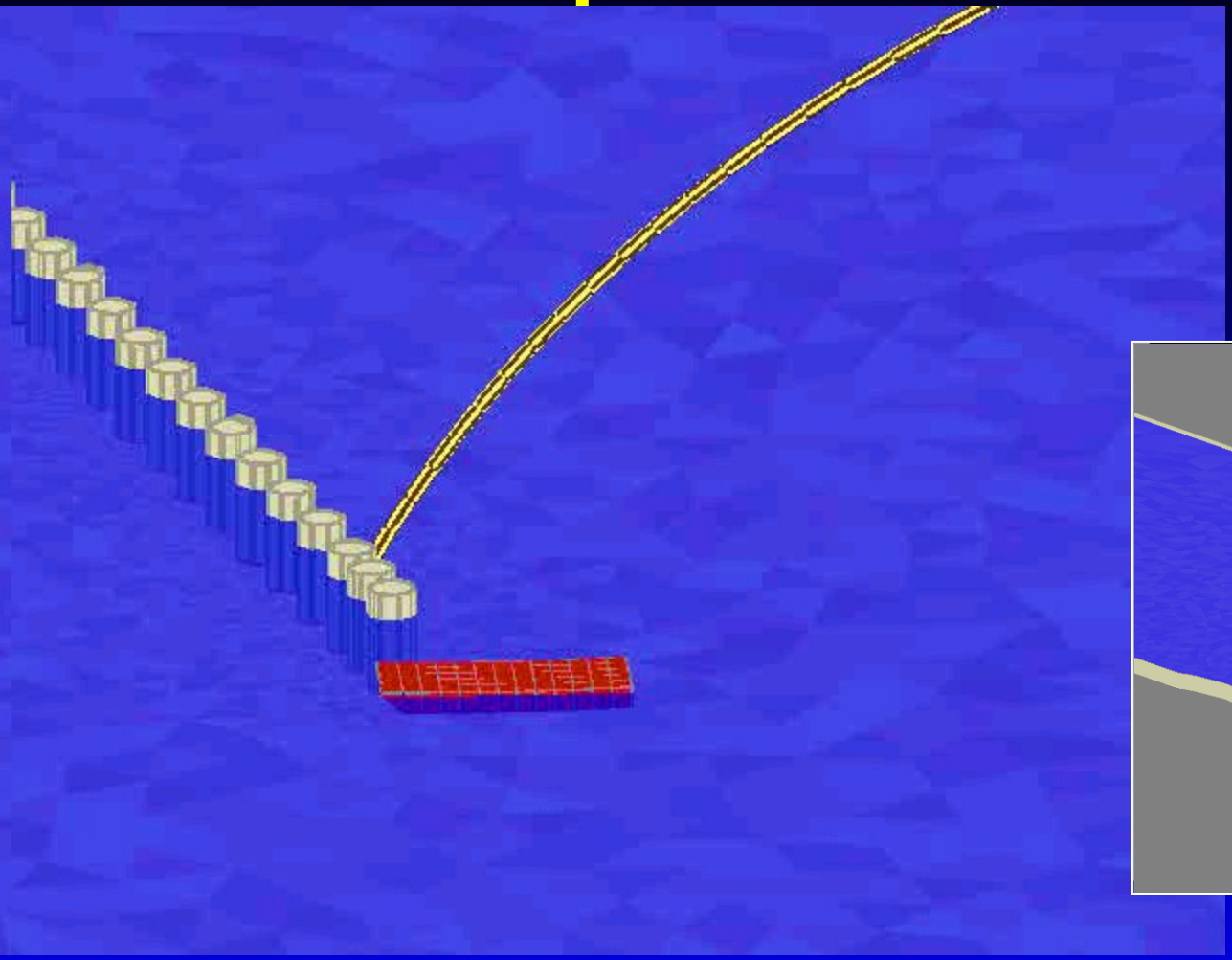
Mesh Adaption during Simulation

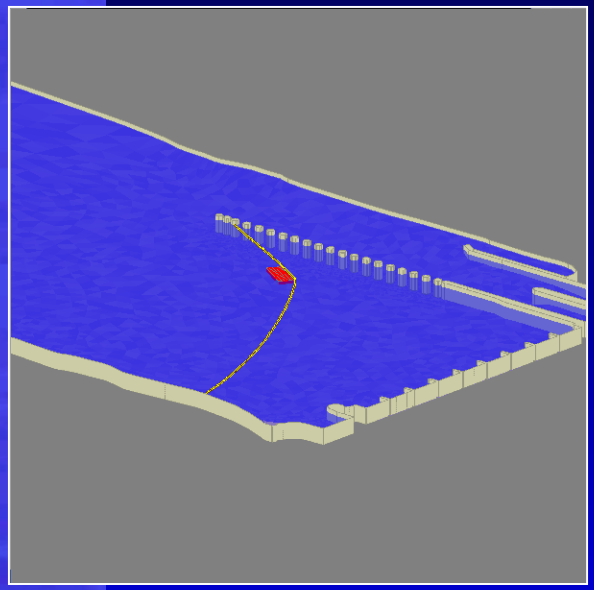


Hydrodynamic Design for Inland Structures: Hydraulic Design and Performance

- **Problems**
  - Design of New Structures and Rehab of existing structures, require improved hydrodynamic design tools
  - **Specifics**
    - **Emergency Closure Structures**
    - **Float-in Construction**
    - **Innovative Lock Approach Structures**
    - **Fish Passage Structures**
    - **Ice/Debris**
- **Benefits**
  - **Increased project reliability**
  - **Increased safety**
  - **Improved design tools**

Concept Design for Vessel Barrier from Coupled ADH and DEM Models

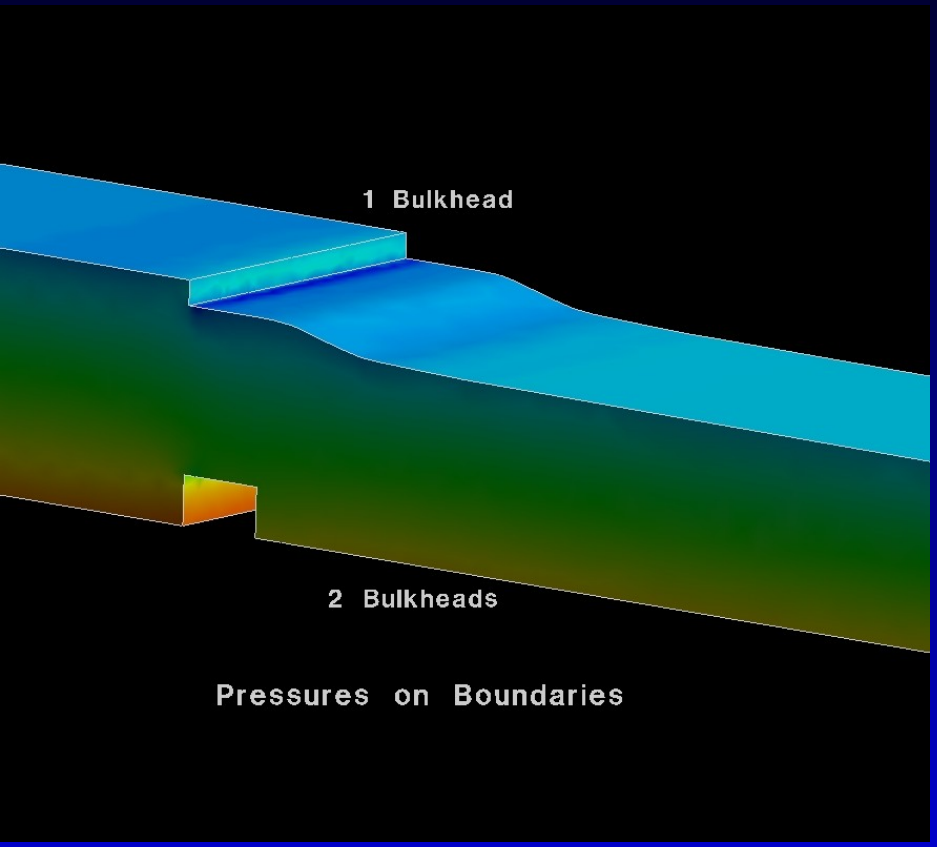




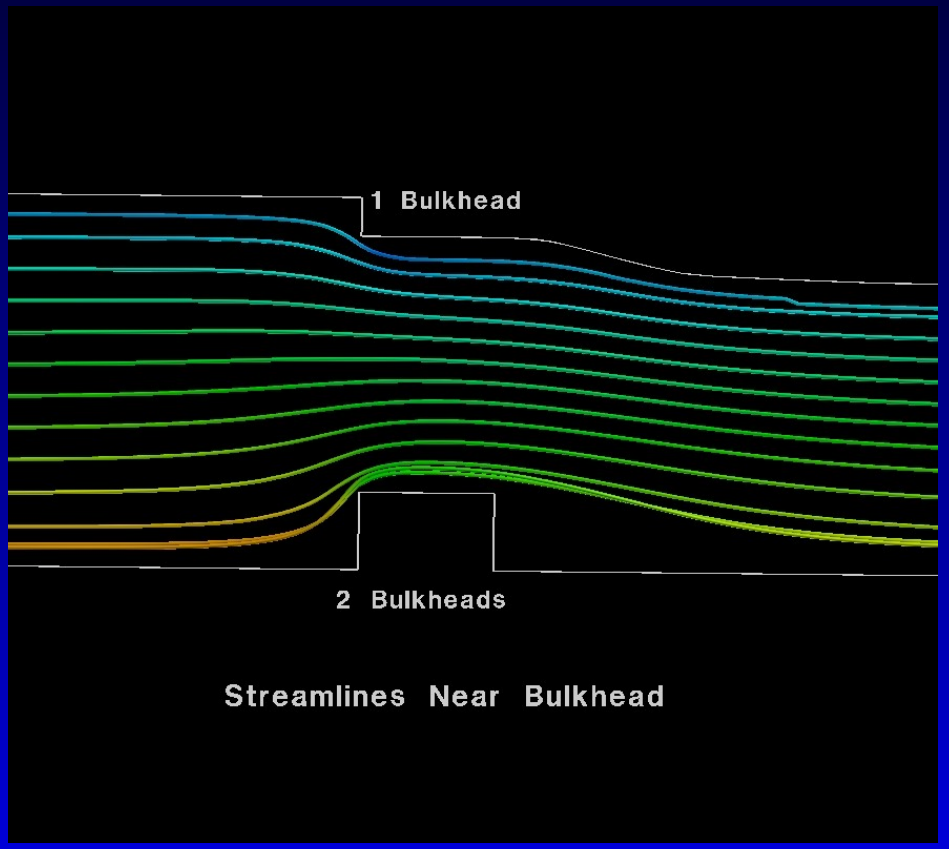
Hydraulic Design of Emergency Closure Structures

- Need to couple the DEM with the 3D Navier-Stokes module of ADH
  - Provide the CoE with a unique modeling ability to address fluid/structure interactions
  - Include forces on valves, gates, and emergency bulkheads deployed in flowing water
  - Applicable to computing hydraulic forces on float-In components

ADH Simulation of Bulkhead Installation



Pressures on Boundaries

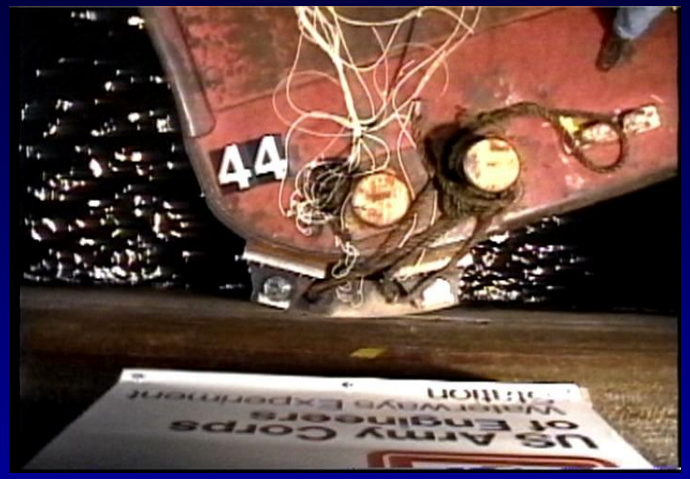


Streamlines Near Bulkhead

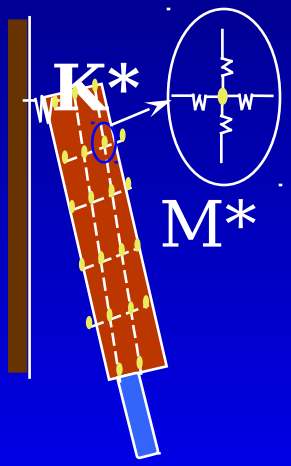
Inland Hydrodynamics and Infrastructure WA

Lock Walls for Barge/Vessel Impact Loads

- **PI: Bob Ebeling**
  - Incomplete Corps Lock wall impact design guidance



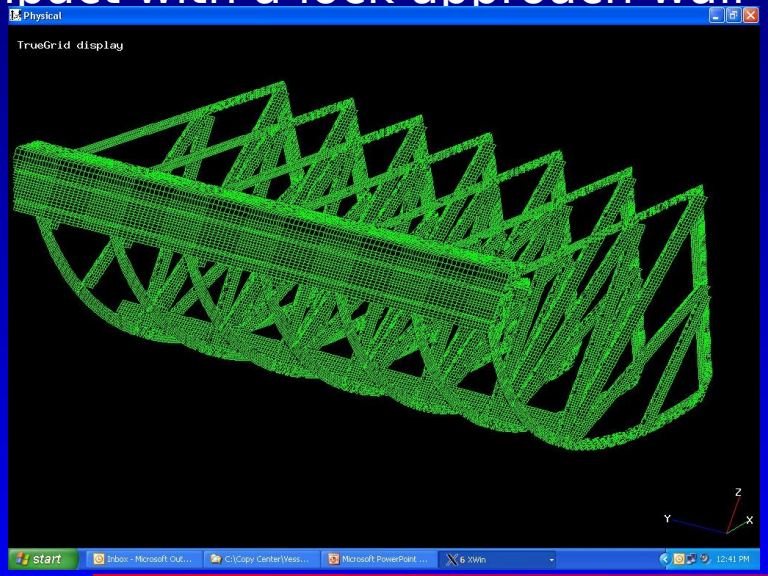
- **Purpose**
  - Complete Corps Lock wall impact design guidance for Barge Impact
  - Develop Corps Lock wall impact design guidance for Vessel Impact



- **Products:**
  - Analytical models of barge impact forces on rigid and flexible (lock) walls
  - Engineering Methodology used in new ETL on Barge Train Impact Forces with rigid walls
  - Guidelines to determine values for vessel impact forces with lock approach walls

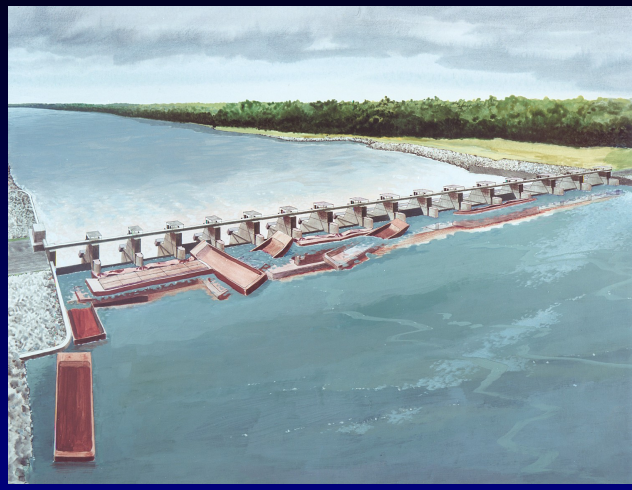
Lock Walls for Barge/Vessel Impact Loads

- **Products (concluded):**
  - Guidelines to determine values of the limiting impact force due to lashing failures within barge trains
  - Guidelines to determine values of the limiting impact force due to plate buckling of the impact corner of a barge during a barge train impact with a lock approach wall



- **Benefits**
  - Optimized Lock Wall Designs, lower costs

Detection and Evaluation of Scour Protection



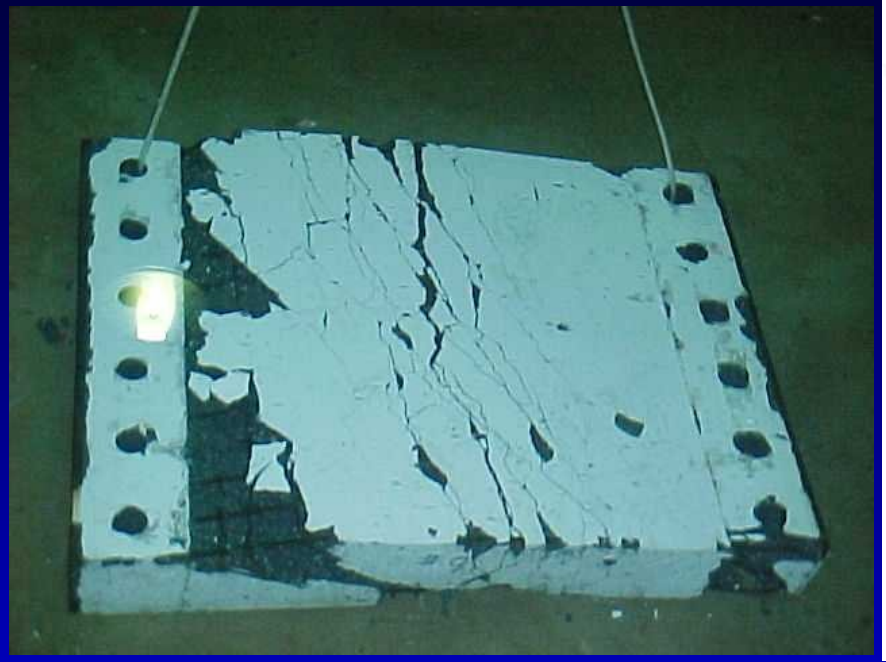
- **PI: John Hite**
- **Problem:**
  - **Scour at dams reduces project reliability; need better tools and guidance to measuring and predicting scour**
- **Products:**
  - Demo project (Emsworth)
  - Recommendations for tools/techniques for scour detection
  - Risk based program for scour protection needs
- **Benefits:**
  - Process to assess repair needs
  - Better prediction of maintenance/rehab costs
  - Reduced chance of failure

Emsworth Scour Protection Study

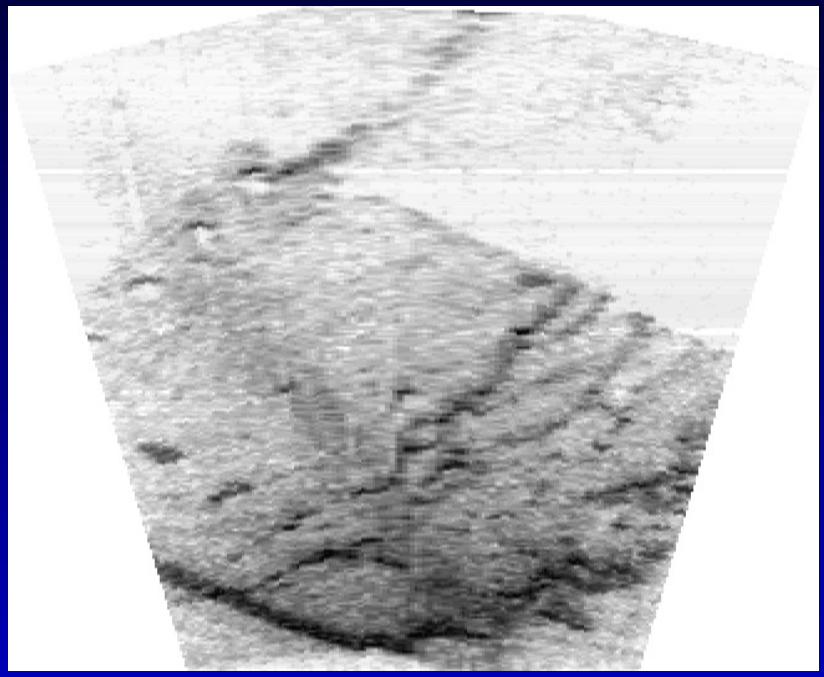
Flow over scour protection

Failure of scour protection

High Resolution Acoustic Imaging System



Concrete Reinforced Block



Sonar Image in Turbid Water

Focus Area - Inland Work Area - Infrastructure

- **Problem**
  - ⇒ Our nation's water highway systems may not be able to meet 21st century demands
    - Most key facilities are approaching or have exceeded their 50-year design life
  - ⇒ Improved understanding of existing condition, relation to strength capacity and remaining service life

- **Products**
  - ⇒ Innovative rehabilitation technologies to extend their life
    - Minimum service disruption and economically viable
  - ⇒ Condition assessment techniques and performance prediction models
    - Manage repair and scheduling tradeoffs

- **Benefits**
  - ⇒ Reduce unscheduled downtime
  - ⇒ Reduce repair costs due to damage and deterioration
  - ⇒ Provide key modules for development of asset management models
  - ⇒ Increase effectiveness in periodic inspections to assess actual structural conditions

Work Units

Soil-Structure Interaction for Seismic Evaluation of Earth Retaining Lock & Cantilever Walls

Inspection and Condition Assessment of Steel Structures

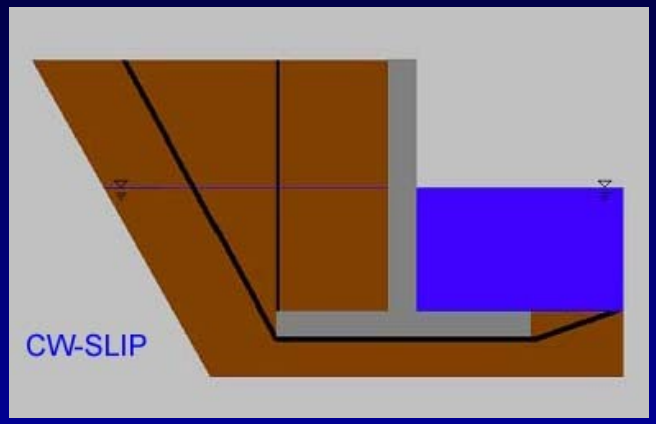
- Steel cracks and welding
- Nondestructive condition monitoring for tensioned steel members
- Acoustic camera for inspection

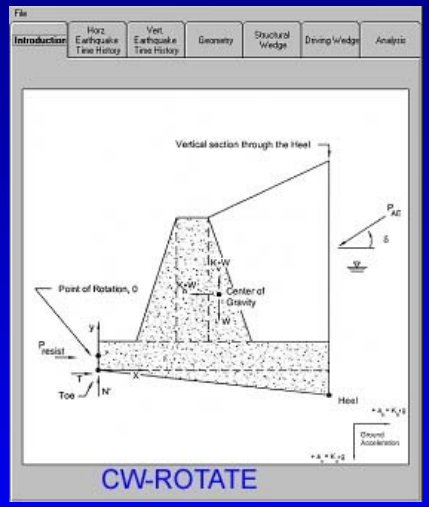
Monitoring and Rehabilitation of Concrete Structures

- Innovative lock rehabilitation techniques
- Monitoring of concrete navigation structures

Soil-Structure Interaction for Seismic Evaluation of Earth Retaining Lock & Cantilever Walls

- **PI: Bob Ebeling**
- **Problem**
  - Incomplete Corps Lock wall design guidance for seismic loading
- **Purpose**
  - Develop Corps Lock and cantilever walls seismic design guidance for walls that slide or rotate during earthquake shaking
- **Products:**
  - Analytical models resulting in seismic forces on walls that slide or rotate during earthquake shaking
- **Benefits**
  - Optimized Lock and Cantilever Wall Designs, lower costs





Steel Cracks and Welding

- **PI: Guillermo Riveros**

- **Problem**
  - Lack of criteria and analytical methodologies for analysis of steel behavior from cracks and welding

- **Purpose**
  - Improve assessment of fatigue and weld cracked gates
  - Study numerical techniques (J-integral) for fracture analysis
  - Assess the connection of miter gate diagonals

- **Products**
  - **Criteria for performing fitness for service assessments**
  - **Analytical techniques for numerical fracture mechanics analysis**
  - **Analytical models to assess the pre-stress requirements of miter gate diagonals**

- **Benefits**
  - **Consistent and systematic guidance for performing a fitness for service assessment**
  - **Detailed fracture analysis**
  - **Reassessment of miter gate diagonal design criteria**

Nondestructive Condition Monitoring for Tensioned Steel Members

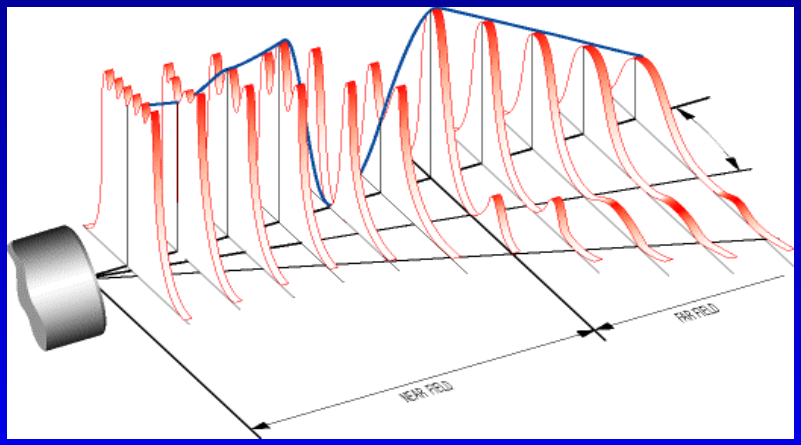
- **PI: Vincent Hock**

- **Problem**
  - **Inability to determine deterioration and loss of strength in critical components**

- **Purpose**
  - **Develop ability to determine condition of embedded structures**

- **Products:**
  - Technology to conduct quantitative measurements of tension and corrosion of embedded steel anchors and steel bracing

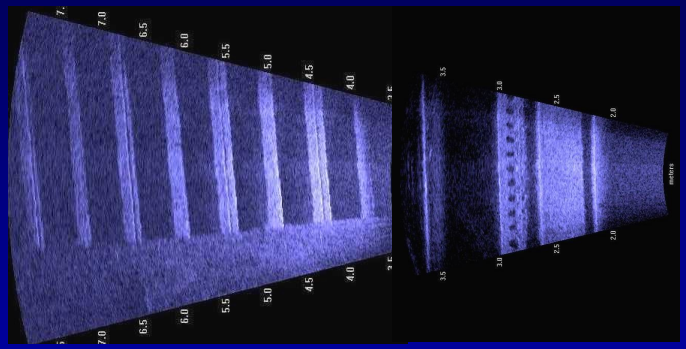
- **Benefits**
  - **Rapid, inexpensive, minimally intrusive condition assessment tool**
  - **High-quality data for effective management and prioritization of limited maintenance resources**



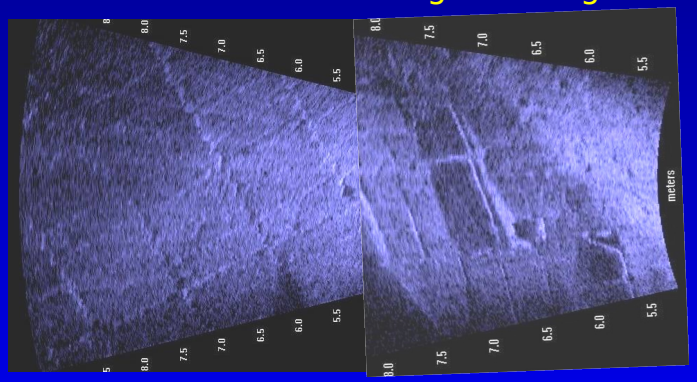
Acoustic Camera Inspection

- **PI: Jim Evans**
- **Problem**
  - Inspection of underwater structures
- **Purpose**
  - To improve inspections through innovative applications, i.e. high resolution acoustical imaging
- **Products:**
  - This will be summarized for FY06 in the form of a technical note and the enhancement of the prototype system
- **Benefits**
  - Improving the quality of inspections, reducing the cost and risk of inspections, and establishing a real time permanent record

Surface ridged casing



Underwater ridged casing



Inspection of Under water matting on MS River

Innovative Lock Rehabilitation Techniques

- **PI: Toy Poole**
- **Problem**
  - Poor performance of constructed and repair material
- **Purpose**
  - Develop technologies to extend concrete service life in navigation structures
  - Freezing & thawing, AAR, surface damage
  - Emphasis on expediency and cost
- **Products:**
  - EM 1110-2-2002 (Evaluation & Repair of Concrete Structures)
  - USACE GS 0391 (Concrete Rehabilitation for Civil Works)
- **Benefits**
  - Improve durability of repairs
  - Extend time until major rehabilitation or replacement

Damage from freezing and thawing

AAR damaged concrete

Monitoring of Concrete Navigation Structures

- **PI: Stan Woodson**

- **Purpose**
  - Develop engineering procedures for monitoring the condition of concrete navigation structures
  - Enhance ability to detect deterioration, identify causes, assess serviceability, predict future performance, and effectively schedule maintenance

- **Products**
  - Training on monitoring techniques and data interpretation
  - Guidance on design parameters to reduce long-term deterioration, assessment techniques, long-term monitoring procedures

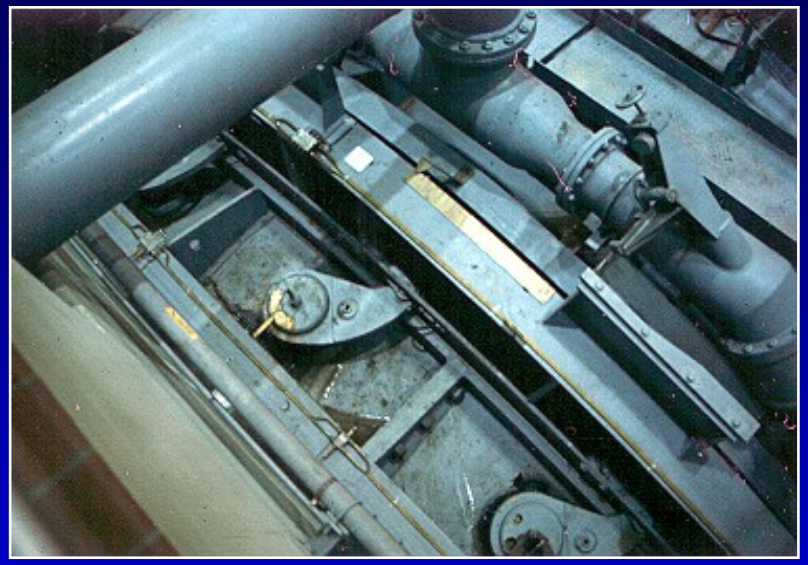
- **Benefits**
  - Ability to develop long-term plans for maintenance and repair to facilitate the effective use of available resources and help insure continued operation of the system

Focus Area - Hydropower

- **Problems**
  - ⇒ Corps hydropower facilities provide 25% of all hydropower in the nation
    - Most are approaching or have exceeded their expected service life
    - Essential to mainline power needs in the Northwestern US
  - ⇒ Need for increased power production efficiency and life of the units, protection against corrosion and deterioration, guidance for selection of lubricants, more cost-effective designs, and predictive performance models
- **Products**
  - ⇒ New turbine-oil guide specifications (comprehensive oil flushing and compatibility test procedures)
  - ⇒ Standardized evaluation procedures for determination of remaining service life of vertical-shaft hydro-turbine-driven generators
  - ⇒ Asset management and system grid reliability tools
- **Benefits**
  - ⇒ Increased operational efficiency
  - ⇒ Reduced unscheduled downtime

Hydropower

- Lubricants in hydro-turbines



Lubricants in Hydro-Turbines

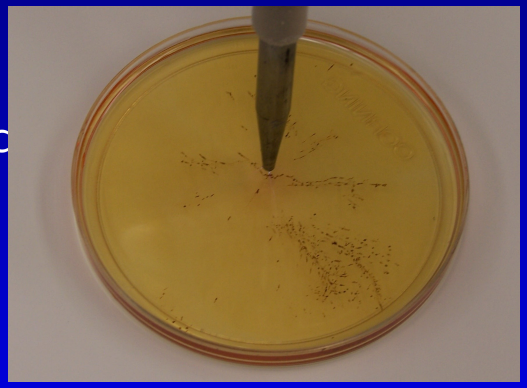
- **PI: Al Beitelman**

- **Problem**
  - New turbine oil manufactured by different process
  - Additives not compatible with those in existing oil
  - No standard to evaluate compatibility of new oil with old

- **Purpose**
  - Eliminate maintenance costs and down time in operation of hydro-turbines

- **Products:**
  - New test method to determine oil compatibility
  - Acceptance as an ASTM standard method
  - Requirements in EM1110-2-1412, Lubricants and Hydraulic Fluids

- **Benefits**
  - Reduced man-hours maintaining equipment
  - Reduced chances of catastrophic failure of bushings



Varnish (sludge) forming during oxidation test

Navigation Networks and Asset Management Focus Area

- **Problems**
  - Commodity Growth to double by 2020
  - Intermodal Challenges
  - Shrinking budget, increasing backlog
  - Aging infrastructure
  - Need for economic tools for life cycle project management
- **Products**
  - Asset management decision support models
  - Engineering Reliability Models
- **Benefits**
  - Peer Reviewed and defensible economic analysis
  - Improved investment of O&M and reduced construction costs
  - Better strategies for national investments
  - Asset Management to support OMB directive

Asset Management and Network Simulation Work Areas

- Economic Risk and Reliability
- Navigation Economic Technologies (NETS)
- Asset Management

Risk Analysis for Major Rehabilitation: Software Toolkit

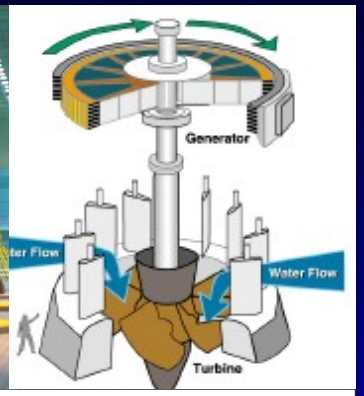
PI: Rolf Olsen (IWR)

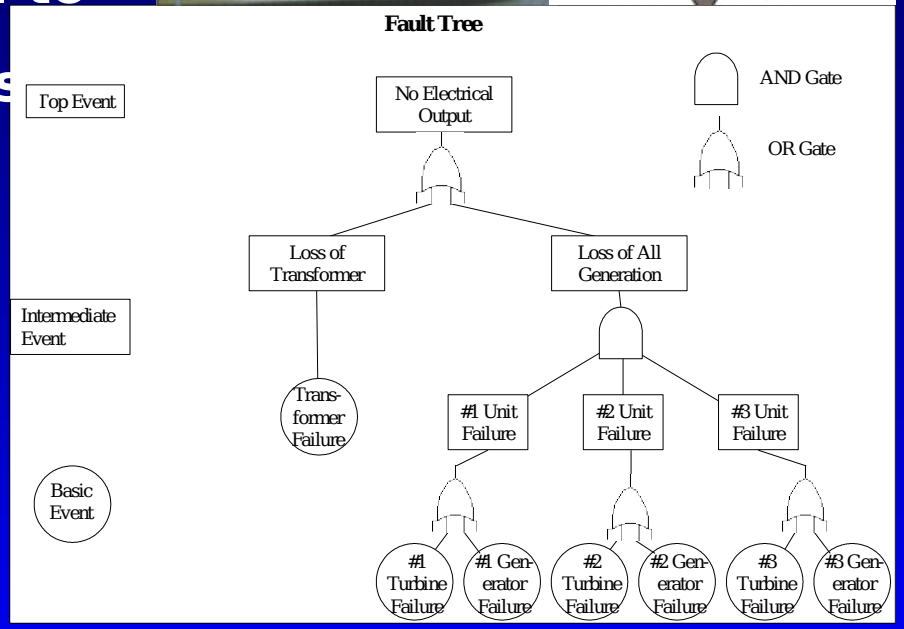
- **Problem:**
  - Lack of certifiable risk analysis software tools for economic evaluation of major rehabilitation projects.
  - Develop generalized software toolkit of risk-based software to assist with life cycle cost analysis.

- **Benefits:**
  - Toolkit with multiple software tools designed for easier training and use.
  - Can address unique major rehabilitation analysis problems.
  - Improved and less costly evaluation of major rehabilitation analysis problems.

Risk Analysis for Major Rehabilitation: Software Toolkit

- **Products:**
  - Previously developed risk-based rehabilitation software tools:
    - Hydropower REPAIR
    - LockSym
    - Hoover Dike model
  - Generalized software tool to be used for major rehabilitation applications
    - Power Plants
    - Navigation Locks
    - Levees
    - Floodwalls
    - Coastal Structures
      - Jetties
      - Artificial Islands
      - Seawalls





Asset Management Work Area

- Improved Reliability Models for USACE Navigation Structures
- Condition Monitoring & Predictive Maintenance for Infrastructure
- Investigation of Corps Navigation Assets

Asset Management

Improved Reliability Models for USACE Navigation Structures

PI: Yazmin Seda-Sanabria (GS

Problem: **Need for improved reliability models to predict actual field performance of Corps navigation infrastructure and assist in future investment planning of critical maintenance.**

- **Currently used mechanical and electrical equipment models are based on annual failure rates, not specific to navigation structures.**
- **Geotechnical models currently used yield inconsistent results on expected operational performance.**

Improved Reliability Models for USACE Navigation Structures

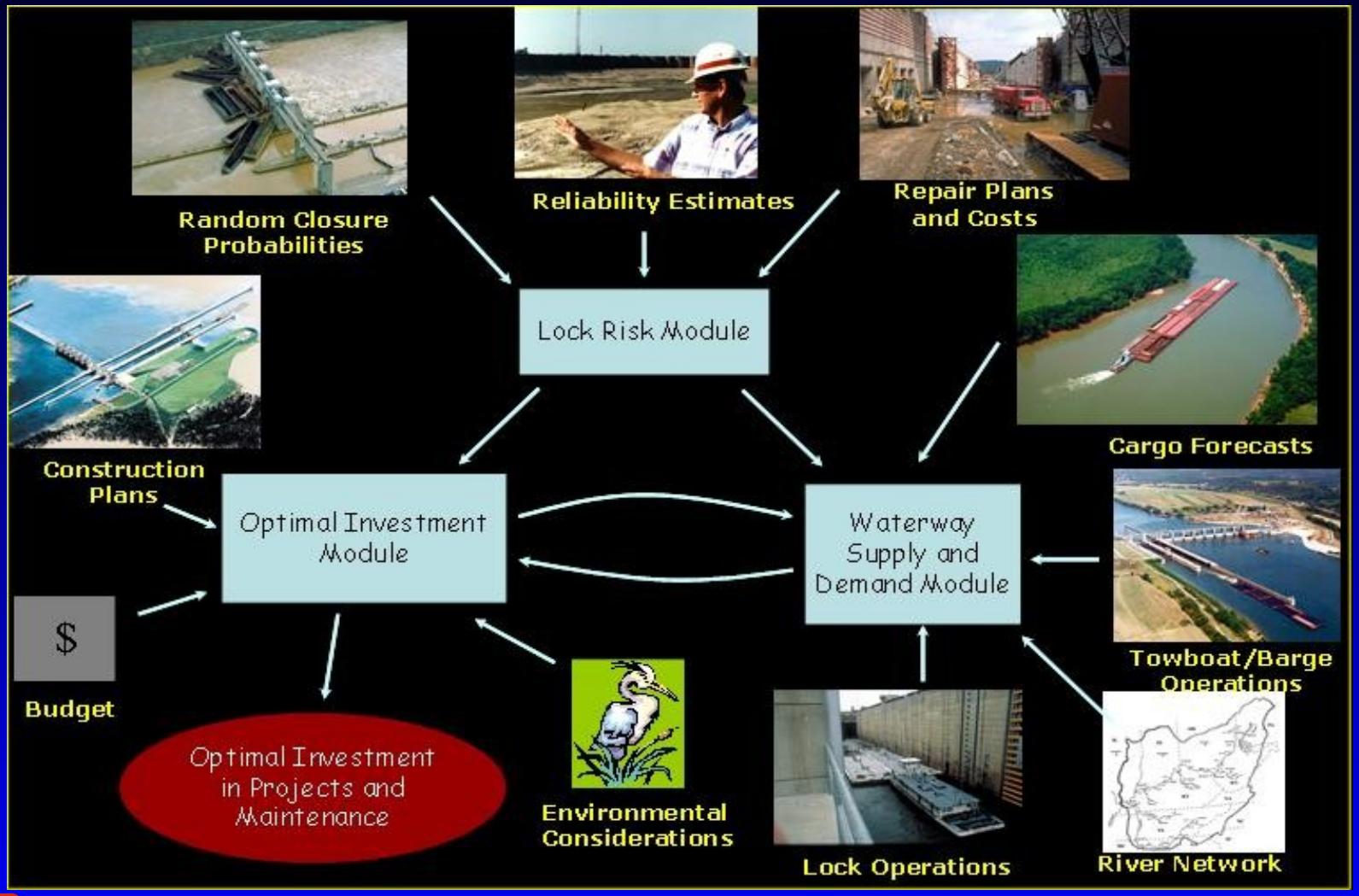
Products:

- **Time-dependent (capacity vs. demand) reliability models for electrical and mechanical operating components (FY06).**
- **Base geotechnical time-dependent reliability models (FY07).**

Benefits:

- **Significant cost savings on critical maintenance (including major rehabilitation) of Corps navigation infrastructure.**
  - **Improved engineering tools that can be integrated into economic models to make risk-based sound investment decisions.**

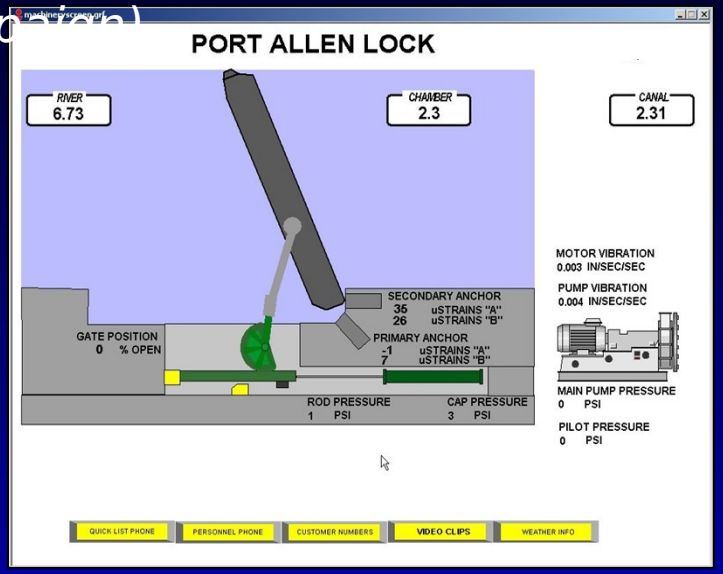
ORNIM


Random Closure Probabilities
Reliability Estimates
Repair Plans and Costs
Lock Risk Module
Cargo Forecasts
Construction Plans
Optimal Investment Module
Waterway Supply and Demand Module
Towboat/Barge Operations
$
Budget
Optimal Investment in Projects and Maintenance
Environmental Considerations
Lock Operations
River Network

Asset Management
Condition Monitoring & Predictive Maintenance for Infrastructure

PI: Ashok Kumar (ERDC-Champaign)

- **Problem:**
  - Unscheduled maintenance can be disruptive and costly
  - Lock and dam gates are subject to failure due to excessive loads and wear of components
- **Products:**
  - Condition monitoring baseline data for:
    - ⇒ Structural components_
    - ⇒ Lock operating machinery
  - Guidelines for Predictive Maintenance
- **Benefits:**
  - Provides real-time indication of overall electrical, mechanical and structural condition
  - Reduces the likelihood of failure of fracture critical components
  - Reduces maintenance cost and personnel requirements
  - Improves safety and reliability of lock gate, dam gate and pumping station operations

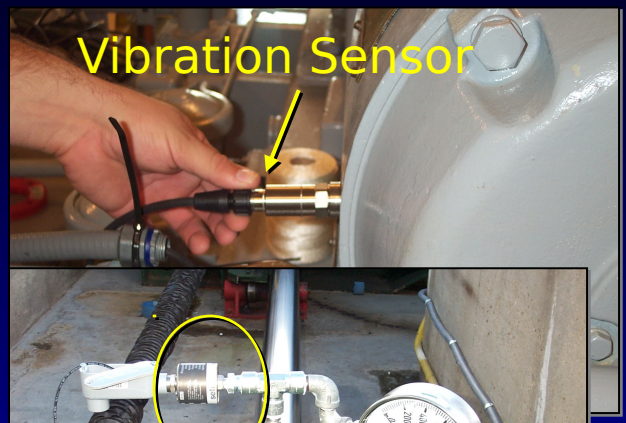


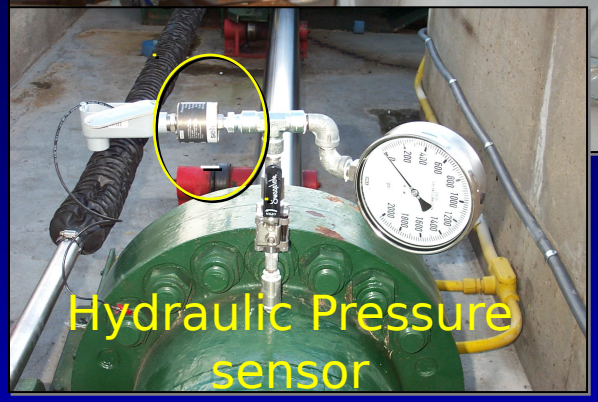
Asset Management
Condition Monitoring & Predictive Maintenance for Infrastructure

FY06 Activities- Port Allen Lock (New Orleans District)

- Establish Condition monitoring baseline data for
  - Lock operating machinery
    - pump motor current, Pump vibration, hydraulic oil pressure
  - Structural components
    - miter gate anchorage loading/strain

- Data acquired will be correlated with gate control machinery movement
  - interfaced to condition monitoring system





Asset Management

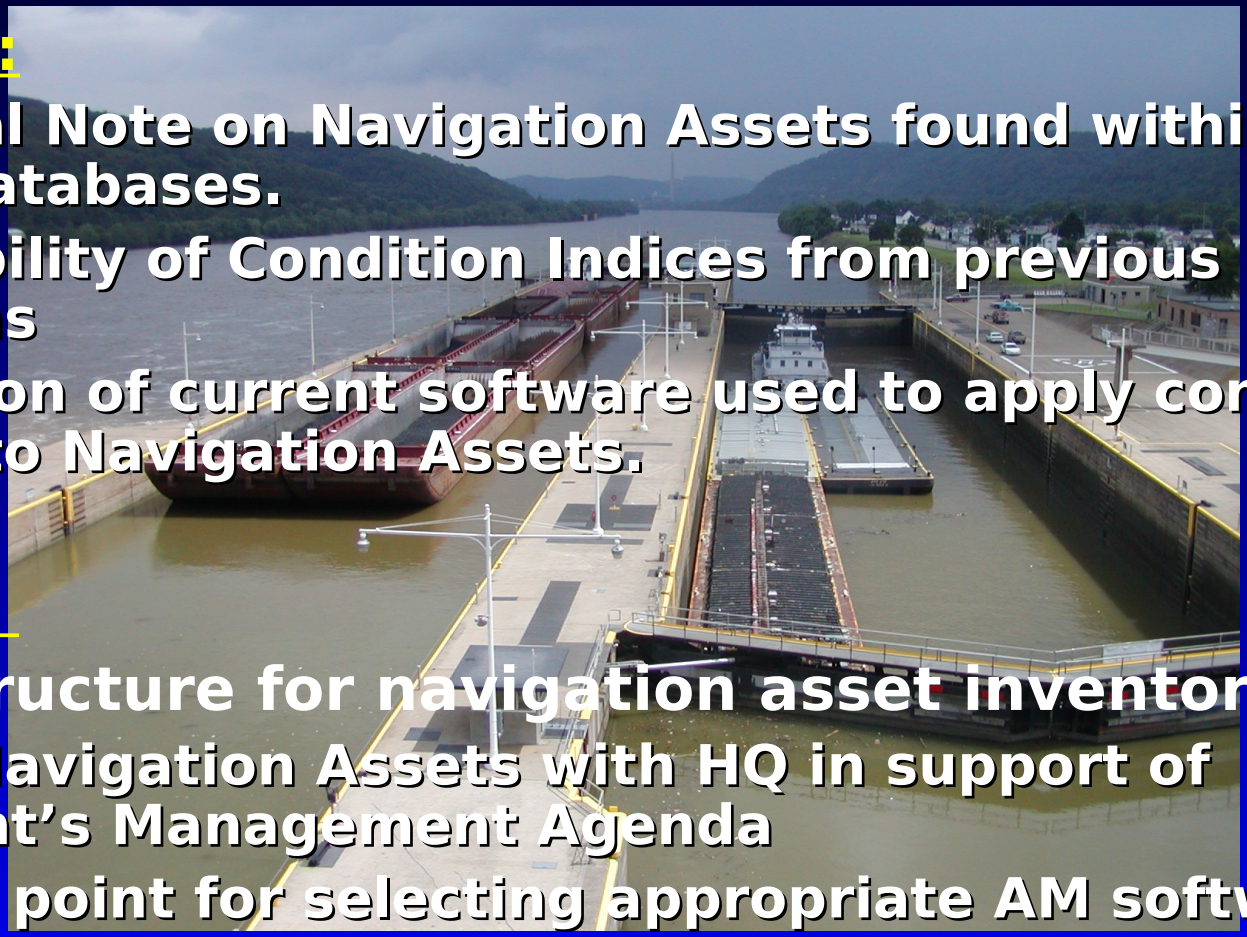
Investigation of the Corps Navigation Assets

PI: Michael Winkler (CHL

Problem:

- Navigation asset inventory undefined
- Lack of specific tools for generalized navigation asset management

Investigation of Corps Navigation Assets



Products:

- Technical Note on Navigation Assets found within Corps Databases.
- Applicability of Condition Indices from previous programs
- Evaluation of current software used to apply condition indices to Navigation Assets.

Benefits:

- Data structure for navigation asset inventory
- Define Navigation Assets with HQ in support of President's Management Agenda
- Starting point for selecting appropriate AM software.

Tech Transfer 05

- Tech Notes – 8
- Tech Reports – 8
- Journal and Conference Papers – 13
- Workshops - 5
- Significant Workshops
  - STWAVE, Bous2D, Pacifica CA, Aug 05
  - Life Cycle Design of Rubblemound Structures, Philadelphia, PA, Jul 05
  - Asset Management, Alexandria, VA, Aug 05

FY06 Workshops – Opportunities for Industry Input

- Feb 06, Currents at Navigation Structures workshop, Vicksburg, MS

- April 18-20, 2006 Lock Inspection and Emergency Repair Workshop, Vicksburg, MS

Navigations Systems MSC Input Desired

- Product Infusion
  - Who
    - Communities of Practice (H&H)
      - Deep Draft (Coastal)
      - Inland
  - How - Methods
    - PDTs
    - Periodic Workshops for CoP – focused and on-site (reduce travel costs)
      - Announce early
    - Others – more effective use of Web – Navigation O&M Portal
  - Role of MSC, CXs

Wrap Up Items

- How to get more field input in Research Programs
- Communication (let folks know what's going on)
- PDTs – how to formalize
- Research Needed